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MJS IMAGING EXPERIMENT

Mariner Jupiter-Saturn Mission
Definition Phase

Addendum to the Report of the OPGT Imaging Science Team

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CONTENTS

1. INTRODUCTION

This addendum to our report "Quantitative Imaging of the Outer Planets and their Satellites" [Feb. 1, 1972. Available on request from the project] is based on discussions at two team meetings held since March, 1972 when the MJS mission was conceived. It gives a brief evaluation of the scientific scope and instrumental potential of the proposed MJS imaging experiment. We have also included our assessment of priorities and trajectory selection criteria which should eventually form the basic strategy for the imaging experiment design.

The MJS imaging system is considerably reduced in scope from the system envisioned for OPGT. Nevertheless, the MJS mission remains an exciting and challenging venture. The removal of the trajectory constraint to fly on to Pluto so reduces the required range of performance margins that the instrumental capability, particularly at Saturn, is effectively enhanced.

Similarly there has been a change in emphasis within the primary scientific goals. For example, the greatly improved trajectory and sequencing opportunities at Saturn have opened up the possibility of a serious Saturn ring experiment for imaging in which it is highly probable that individual ring components will be resolved. Similarly the opportunities for observing most of Saturn's satellites, particularly Titan and Iapetus, are enormously improved. Of course, many unique scientific circumstances disappeared with the loss of Uranus, Neptune, their satellites and Pluto. For example, the possibility of broad comparative studies of different families of outer planets is temporarily delayed. Nevertheless, the fact is that with MJS our ability to perform a detailed comparison of two planets in the same family has been considerably enhanced.

It is the opinion of the Imaging Science Team that the proposed MJS mission TV-experiment will amply reward those scientists willing to commit themselves to it.

2. IMAGING SCIENCE OPPORTUNITIES ON MJS

A. Scientific Opportunities in Imaging

The following table lists five major areas which broadly represent the domain of Imaging Science on MJS. The table also includes specific examples of types of experiments

in each area. This compilation is illustrative of investigations that can actually be carried out with the baseline TV system and is not a comprehensive tabulation of every conceivable project. [A detailed discussion of the general nature of outer planet scientific opportunities is contained in the Feb. 1, 1972 report.]

I. EXPLORATORY IMAGING

A search for novel and unanticipated physical phenomena. These could be connected with atmospheric motions and satellite surfaces at high resolution; aurorae; satellite shadows; the flux tube connecting Io to Jupiter; meteorite influx; lightning; the dynamics and structure of Saturn's rings; etc.

II. ATMOSPHERIC PHENOMENA ON JUPITER AND SATURN

(a) Comparative studies of global motions and cloud distributions on Jupiter and Saturn.

(b) Gross dynamical properties: zonal rotation (particularly Saturn and at high latitudes), orientation of spin axis, large scale zonal shear, large scale vertical shear, pattern and time development of flow instabilities, interaction of localized dynamical regimes (i.e., spots, festoons, disturbances), spectrum of the scale of atmospheric motions in time and space.

(c) Mode of release of internal energy flux: search for convection cells or rolls.

(d) Study of the growth, dissipation, morphology (terminator studies), and vertical structure of cloud complexes - perhaps extended to the scale of individual clouds.

(e) Gross optical properties: global, and to some extent localized, scattering function in the visible spectrum, coarse polarimetry. Nature of chromo phores, their structure and development.

(f) High resolution study of Great Red Spot.

III. SATELLITE STUDIES

(a) Gross characterization: size (general better than ±10 km), shape, rotation, spin axis, cartography, improved ephemerides and masses [connected with approach guidance effort].

(b) Geology: major physiographic provinces, impact features, orogeny, volcanism, lineaments, polar caps, comparative studies of low and high density satellites, erosion processes.

(c) Detection of atmospheres (past or present). Clouds, hazes, distribution and lifetimes of frosts, limb stratification of aerosols, polar caps.

(d) Surface properties: microstructure inferred from colorimetry, scattering function, coarse polarimetry. The nature of brightness variation (particularly in the case of Iapetus).

(e) Search for new satellites; a confirmation of the nature of Janus.

IV. SATURN RING STUDIES

(a) Resolution of individual ring components or clumps of material.

(b) Vertical and radial distribution of material at very high resolution.

(c) Scattering function, coarse polarimetry.

(d) Occultation; optical depth.

(e) Attempts to distinguish different types of material in the rings.

V. OTHER OBJECTIVES

(a) Search for new comets and asteroids.

(b) Targets of opportunity.

B. Some Suggested Guidelines for Establishing Scientific Priorities in the Imaging Experiment

In planning the execution of the imaging experiment and the details of the instrument and its ancillary equipment conflicting requirements will often arise. It is therefore necessary to have a broad set of priorities defined so that choices can be made and conflicts resolved in a logical manner. In compiling

the list of priorities given below we have been strongly influenced by the interest in making comparative studies of planets and satellites, and secondly by the probability that Jupiter will be intensively investigated by other more specialized missions in the next one or two decades.

(i) The Jupiter and Saturn systems have equal scientific priority and should be studied under similar conditions of lighting and viewing.

(ii) In the event of mission-imposed constraints on choice of targets or instrumental capability, the Saturn system has priority over Jupiter.

(iii) Satellite, planet, and ring studies have equal priority.

(iv) It is essential that Jupiter and Saturn are each observed over long enough periods of time (greater than 2 days) above 100 kilometers resolution to permit proper study of dynamical phenomena. A similar allowance must be made for studies of satellite rotation (or atmospheric phenomena on Titan).

(v) At least one low density (<2 gm/cm^3) satellite, preferably in each planetary system, should be studied at resolutions approaching 1 km with wide coverage. A high density object in each system should also be studied for detailed comparative information.

(vi) The satellites of greatest interest in the Jovian system are Io and Callisto; in the Saturn system they are Titan and Iapetus.

(vii) As many satellites as possible should be observed at better than 15 km resolution to permit intercomparisons of size, shape, density, surface structure, and morphology.

3. COMPLIMENTARY SCIENCE EXPERIMENTS: OPPORTUNITIES FOR COOPERATION

On March 9, 1972 the MJS-SSG passed the following resolutions: "The SSG strongly recommends that every effort shall be made to avoid proliferation of experiments in a single discipline, especially those with overlapping objectives with consequent elimination of desirable experiments in other areas." Among the experimental areas represented on the SSG with over-

lapping objectives and in some respects instrumental similarities are Imaging, Infrared radiometry and spectroscopy, and Photopolarimetry. The imaging science team believes that much greater efforts should be made to enhance the complementarity of these disciplines. For example, if a study of the dynamics and energetics of the atmospheres of Jupiter and Saturn is to be a prime mission objective then a priority must be set on the design of both imaging and IR instrumentation which will ensure maximum complementarity in the experiments; even though other non-overlapping objectives in the two fields may be compromised.

A second area that could be pursued with more vigor is the possibility of combining instrumental capability. An example here is the possible use by parts of the IR experiment and the photopolarimetry experiment of the optics used in the imaging experiment. These instruments are generally boresighted for maximum effect and we wonder whether substantial savings in cost, time, and weight might accrue from some closer coordination of these experiments.

4. BASELINE IMAGING SYSTEM

A. Brief Evaluation of Capabilities

The basic properties of the baseline TV hardware (excluding data system) are very similar to that of Mariner 9 and are described in detail in the accompany spacecraft description document. Below we briefly outline the general usage and limitations on the imaging system.

(i) Narrow angle/wide angle lens combination: The team endorses the choice of a narrow angle/wide angle camera combination and offers the following justifications and use for each camera:

Narrow Angle (Long Focal Length):	To maximize the time (observatory phase) above a given spatial resolution for study of dynamic phenomena in atmospheres and satellite rotation rates.
	To maximize the range of spatial scales of atmospheric phenomena that can be observed down to individual cloud elements.
	To provide coverage at moderate resolution of many satellites for comparative studies.

	To provide limited coverage of a few satellites and the rings of Saturn at resolutions of one kilometer or better.
	To provide reasonable surface coverage at high resolution when a dark side pass is necessary for an occultation experiment.
Wide Angle (Short Focal Length):	To provide full coverage at moderate resolution of the planetary terminator and to maintain, as far as possible, global surface coverage on satellites during flyby.
	To enhance the physical interpretability of the narrow frames through nested wide coverage moderate resolution frames.
	To extend in time, global coverage of dynamic phenomena in atmospheres above a given resolution during near encounter.

(ii) Sensitivity and spectral response:

The surface brightness of Saturn in visible light is down by a factor of 10 from that of Mars. This factor is not anticipated to cause exposure problems under high lighting conditions with wide band filters but may curtail high resolution imaging in the terminator regions.

The spectral response of the selenium vidicon starts at 0.35 microns, peaks at 0.40 microns, and falls off rapidly beyond 0.5 microns. This factor prevents quantitative narrow band imaging in the methane and ammonia absorption regions.

(iii) Capability for time coverage above a given resolution:

The table below gives a rough guide to the capability of the baseline system (.5 m focal length). This data is trajectory dependent and is based on current SSG trajectories [J (Apr. 16,'79), T, S (Feb. 16, 1981), and J, S (May 4, 1981), I].

MJS '77: TIME COVERAGE ON APPROACH (DAYS)

Resolution	Jupiter .5m	Saturn .5m	Titan .5m	Iapetus .5m
3000-km resolution	50	38	-	-
1500-km resolution	25	19	~19	~20
Fills .4 FOV	18	12	0.4	0.15
500-km resolution	8	6.5	5	6
Fills .8 FOV	9	6	0.2	0.07
300-km resolution	5	4	3	4
100-km resolution	1.6	1.2	1	1.7

It is the team's opinion that imaging studies of dynamic phenomena in atmospheres increases significantly with global coverage and when the length of observing time above a particular spatial resolution is maximized. In the case of Jupiter and Saturn it is anticipated that atmospheric motions become quasi-geostropic at scales of about 100 kilometers and we suggest on the basis of simple scaling arguments, that 2 days, or five planetary rotations, is the minimum desirable observing period. With this in mind it would appear that the baseline system could be tremendously improved with a one meter focal length narrow angle camera. However, the sensitivity problem mentioned in (ii) above and the attitude stability of the spacecraft should be carefully weighed before recommending such a change.

(iv) Capability for coverage at a given resolution.

The capability of the imaging system is presently in considerable doubt because:

(a) Spacecraft power restrictions may (i) prevent slewing of the scan platform while recording data, and (ii) may lead to turning off the TV system during Saturn occultation. The team is trying to find ways with the project to alleviate these problems.

(b) Uncertainty in the optimum choice of trajectory. Some idea of the resolutions that can be achieved for the Jupiter (Apr. 16, 1979)/Saturn (Feb. 16, 1981) trajectory are as follows:

Body	Distance (km)	Maximum Surface Resolution (km) 0.5m	1.0m	Maximum Angular Diameter (degrees)
Jupiter	349,000	20.9	10.5	9.8
Io	39,800	2.4	1.2	2.2
Europa	650,000	39.0	19.5	0.13
Ganymede	229,000	13.7	6.9	0.63
Callisto	292,000	17.5	8.8	0.45
J5	493,000	29.6	14.8	-
J6	9,560,000	573.6	286,8	-
J7	4,030,000	241,8	120.9	-
Saturn	77,900	4.7	2.3	25.9
Mimas	294,000	17.6	8.8	0.05
Enceladus	173,000	10.4	5.2	0.11
Tethys	160,000	9.6	4.8	0.18
Dione	301,000	18.1	9.0	0.08
Rhea	394,000	23.6	11.8	0.10
Titan	8,480	0.51	0.25	12.91
Hyperion	1,110,000	66.6	33.3	0.01
Iapetus	2,970,000	178.2	89.1	0.01
Phoebe	5,530,000	331.8	165.9	-

(v) Data return capability.

The imaging system can shutter 2057 frames/day. The spacecraft telemetry system can return this quantity of data in real-time from Jupiter and approximately 40% of this data quantity from Saturn under nominal conditions. With reasonable compression or editing of data real-time operation at Saturn should be possible.

B. Suggested Areas from Instrumental Development

(i) The focal length of the narrow angle camera might be increased to as much as one meter to improve the experiment profile. However, the resultant sensitivity and pointing capability of the system should be carefully considered.

(ii) An optical redesign should be done which will provide more area and flexibility in the focal plane region than is available in the M '71 design. Provision should be made for incorporating photometric point or array detectors in this area (cf. Section 3 of this report).

(iii) An optical switch (at least one time operable) should be included in the design to provide extra reliability for the narrow angle camera mode.

(iv) An auto exposure capability should be included in the system.

(v) Gross uncertainties in satellite ephemerides indicate that an "encounter satellite sensor", which can automatically point and stabilize the scan platform, should be included on the spacecraft.

(vi) An active program to solve the residual image problem should be initiated.

5. TRAJECTORY AND SEQUENCING CRITERIA

The extremely complicated problem of selecting the optimum trajectories for the two MJS spacecraft has barely begun. In this section we have included a list of imaging criteria, often contradictory, on which to base a search for the best trajectories and also to illuminate the areas in which compromises

will be necessary. These criteria represent our first attempt to answer the question: "What kind of a trajectory does the imaging science experiment require?"

(i) The trajectory should pass close to Saturn, but not too close. A reasonable requirement is that, during the brief period of terminator viewing, full coverage of the terminator region at the high resolution should be obtained with the wide angle camera. Trajectories should probably pass at about an altitude of three planetary radii.

(ii) The trajectory at Saturn should pass through the ring plane outside of the A ring but sufficiently close to provide high resolution viewing edge-on that is compatible with instrument sensitivity and smear.

(iii) The trajectory should optimize the perpendicular distance to the ring plane to maximize the probability of resolving individual ring components. This implies minimizing the slant angle to the outer ring and adjusting the distance to be compatible with instrument sensitivity and smear.

(iv) Items (ii) and (iii) above imply trajectories at moderate inclination to the ring plane.

(v) The trajectories should allow the imaging system to achieve ~1 km resolution with substantial surface coverage on both Titan and Iapetus. These trajectories should, at the same time, attempt to provide good viewing possibilities at Io and Callisto in the Jupiter system.

(vi) Iapetus encounter should occur when both forward and trailing hemispheres are illuminated to some degree. This generally implies encountering Iapetus near solar conjunction or opposition (as seen from Saturn), or arranging the individual trajectories to be complimentary.

(vii) The trajectories should maximize the possible phase angle coverage of as many objects as possible, particularly Saturn.

(viii) The trajectory should not pass through the observable rings.

Detailed sequencing normally follows the choice of prototype trajectories. However, the following areas require the immediate attention of the flight team.

(i) The sequencing capability of the tape recorder should be immediately discussed. Restricting the capability to full tape readouts may seriously impact the optimum sequencing strategy for studying dynamic phenomena on Jupiter and Saturn.

(ii) The requirements for scan platform usage must be quickly evaluated to ensure that sufficient capability to reach all of the satellites at a wide selection of phase angles is available.

(iii) The effects of the choice of occultation trajectories on imaging strategy and system design must be evaluated.

(iv) The compatibility of approach guidance and imaging science requirements remains to be evaluated.